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EMISSIONS TO THE ATMOSPHERE FROM EIGHT MISCELLANEOUS SOURCES IN OIL REFINERIES

Joint District, Federal and State Project for the Evaluation of Refinery Emissions

June 1958

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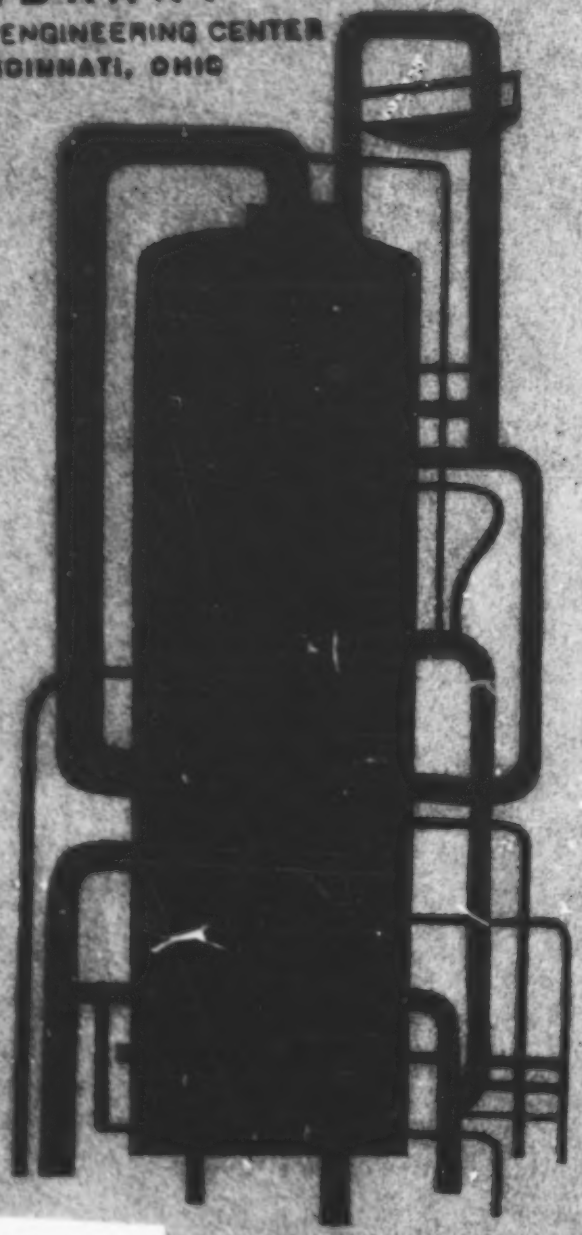

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REPORT NUMBER 8

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Details of illustrations in this document may be better studied on microfiche.

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FOREWORD

In August, 1955, the Los Angeles County Air Pollution Control District, the U. S. Public Health Service, and the California State Department of Public Health inaugurated the Joint District, Federal, and State Project for the Evaluation of Refinery Emissions in Los Angeles County. The Western Oil and Gas Association, representing the petroleum industry, also participated in the project. This report presents the results of studies of eight miscellaneous sources in petroleum refineries.

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EMISSIONS TO THE ATMOSPHERE FROM EIGHT MISCELLANEOUS SOURCES IN OIL REFINERIES

IN BRIEF

This report details the techniques and results of Joint Project studies of atmospheric emissions from eight miscellaneous sources in oil refineries. Because the emissions from these operations or equipment were of a minor nature or were already well defined and understood through previous available studies, independent field testing was carried out in only one of the eight source studies. The estimates of emissions presented were generally based on field inspections, letter surveys, literature surveys, and existing test data or loss estimates supplied by the Los Angeles County Air Pollution Control District or the Western Oil and Gas Association. Table 1 summarizes the results of each study.

Air Blowing

Tests were made on four of the seven air blowing units operated by Los Angeles County oil refineries. The test method involved drawing a measured sample of the exhaust air through cold traps. The condensate and gaseous content of the traps were analyzed for hydrocarbons. The results of the four tests, extrapolated to all units, indicated a daily emissions of about 0.5 ton of hydrocarbons.

Blind Changing

All oil refineries in Los Angeles County were contacted and requested to keep an accurate record for two months of all operational blind changing activity for stocks having a volatility higher than kerosine. The information requested included type of blind, vapor pressure of product, type of surface beneath the blind (concrete, steel plate, earth, etc.), type of flushing employed, distance to the nearest drain and estimate of the amount of product spilled during the blind changing operation. Evaluation of the survey data indicated emissions to the atmosphere from blind changing operations of 200 pounds of hydrocarbons per day.

TABLE I

EMISSIONS TO THE ATMOSPHERE FROM EIGHT MISCELLANEOUS SOURCES IN PETROLEUM REFINERIES

Source Equipment or Operation	Method of Study	Emissions to Atmosphere	
		Hydrocarbons, Tons per day	Remarks
Air blowing	Field testing	0.5	As hexane by IR
Blind changing	Letter survey and calculations	0.1	
Loading facilities	Calculations	0.9	Most racks have vapor recovery
Turnarounds, equipment maintenance, and blowdown systems	Calculations	2.0	
Waste water separators and process drains	Field inspections and existing APCD estimates	3.0	Separators covered
Gas compressor internal combustion engines	Calculations based on refinery-supplied test data	6.5	90% methane; also 4.5 tons per day NO_x and some NH_3 and HCHO
Waste gas flares	Field inspections and refinery-supplied test data	Negligible	All flares smokeless
Vacuum jets	Review of control devices	Negligible	All jets under vapor control

Loading Facilities

All refineries were requested to submit information concerning type of product and volumes loaded. It was considered that no emissions occurred from the major loading installations which are controlled by vapor collection and disposal systems. The hydrocarbon emissions to the atmosphere from the uncontrolled loading facilities were calculated and amounted to about 1800 pounds per day.

Turnarounds, Equipment Maintenance and Blowdown Systems

Questionnaires were sent to all major refineries in the County requesting detailed information on the number and types of shutdowns during the period of September 1956 to September 1957, and the size of the units involved. Additional information was requested for all tank maintenance operations. For shutdowns with possible emissions the magnitude of hydrocarbon emissions was estimated by assuming that the emission was equivalent in weight to the total volume of the unit filled with butane vapor at standard conditions. The emissions from each tank cleaned during the one-year period were also calculated using the survey data. The average hydrocarbon emissions to the atmosphere from shutdowns and tank maintenance was 2 tons per day.

Waste-Water Separators and Process Drains

Field inspections were made of oil-water separators and process drainage systems in all major refineries in Los Angeles County. During these field trips a number of tests were made of the hydrocarbon concentrations in and around the equipment using a combustible gas indicator. A smoke generator was used to indicate air flow through the units. The data from these inspections concerning hydrocarbon emissions to the atmosphere from this source agreed with the existing data of the Air Pollution Control District. Three tons of hydrocarbons per day are emitted to the atmosphere from waste-water separators and process drains.

Exhausts of Gas Compressor Internal Combustion Engines

A census of all major refineries was taken concerning operations of gas compressor internal combustion engines and correlated with available test data. The refinery test data were evaluated and extrapolated to the total exhaust rate. These calculations indicated the following emission rates:

Hydrocarbons (90% methane)	6.5 tons per day
Oxides of Nitrogen, as NO_2	4.5

Waste Gas Flares

All waste gas flares used in local refineries are either venturi or steam injected installations. Both types are known as smokeless flares. The study of emissions from flares involved field inspections, a review of permit applications submitted to the Air Pollution Control District, a literature survey and an analysis of available test data. It was concluded that essentially complete combustion occurs in smokeless flares and therefore the emissions of organics and particulate matter are negligible. Emissions of oxides of sulfur and nitrogen are possible but no estimate of the amounts are available from this study. The flares operate only occasionally to dispose of gases released because of some abnormal plant condition.

Vacuum Jets

At the time of inauguration of the Joint Project, vacuum jets were a source of hydrocarbon emissions and were listed for study. At the present time all vacuum jet installations are controlled and no atmospheric emissions result from their operation.

INTRODUCTION

The original outline of the Joint Project noted 16 sources of possible air pollution in oil refineries and called for a detailed evaluation of each source. Particular emphasis was placed on the emission of hydrocarbon vapors. These evaluations were to be based on original Joint Project data obtained through field testing or other appropriate surveys and were to be independent of previous studies. This independence was maintained in studies involving all equipment or operations having emissions of unknown or suspected large magnitude. Evaluation of these sources necessitated major surveys or field testing programs which have been described in detail in previous Joint Project publications (1)*.

Upon completion of these major testing programs, the eight remaining sources were reviewed by the Joint Project Committee. It was determined that:

1. Sufficient information was available from previous emission studies or analysis of the equipment or operations to indicate that emissions from these remaining sources were not of major importance.

2. Field testing for most of these sources would necessitate a long, involved program usually including the development of a unique sampling or analytical technique.

3. Complete tests on these remaining sources would extend the completion date of the Joint Project far beyond the initial expectations.

The Committee concluded that studies of the remaining sources should be limited in scope and should utilize available data where possible.

The sources which were investigated by a limited study in this final phase of the Joint Project include the following equipment or operations:

Air blowing
Blind changing
Loading facilities
Blowdown systems, turnarounds, and equipment maintenance
Waste water separators and process drains
Gas compressor internal combustion engine exhausts
Waste gas flares
Vacuum jets

* Numbers in parentheses indicate references listed on page 50.

SECTION 1

AIR BLOWING

Introduction

Air blowing is a minor operation performed in only three Los Angeles County refineries operating a total of seven air blowing units. At the initiation of this testing program, four refineries operated a total of ten air blowing units. During the Joint Project's initial resting program, air blowing operations in three units were discontinued, and the operation of another unit is scheduled to be discontinued in the future.

Air is blown through petroleum fractions for brightening (removal of turbidity due to moisture) and for agitation during treating. The atmospheric effluent from these operations contains hydrocarbon vapors and aerosols.

The total emissions to the atmosphere from air blowing operations in Los Angeles County are relatively small compared to the total of all hydrocarbon emissions from refinery operations. However, the emissions from an individual unit could be large enough to warrant consideration. Only the emissions from units in operation at the time of the writing of this report will be discussed.

Description of Units and Location of Sampling Points

In the following description of the process equipment code letters and numbers are used to designate the various units tested and they are listed in the order in which they were tested.

Units C-1, C-2, C-3, C-4, C-5

Air is blown into these five tanks to agitate diesel oil, jet fuel or kerosine during chemical treatment (See Figure 1-1). This is a batch operation. Two of the units have capacities of 2000 barrels each and the other three units have capacities of 1000 barrels each.

Compressed air is introduced at the bottom of the agitator vessels at a rate of 300 to 400 SCFM. The total blowing time for all five units is 6.5 hours per day.

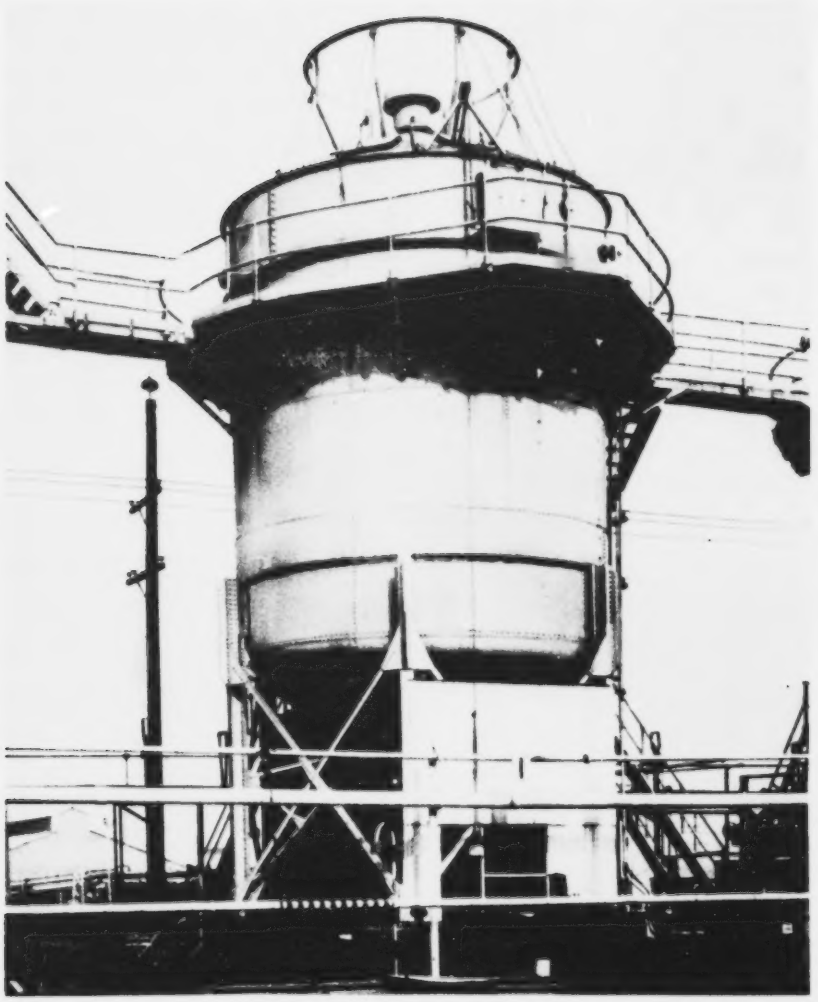

Figure I-1. Treating tank using compressed air agitation.

Each vessel is covered by a conical roof. A vent, equipped with a rain cap, is set in the roof. This vent discharges directly to the atmosphere but is inaccessible as a sampling location because of the tapered roof. Each vessel is provided with an access door set in its side near the top (about 8 feet above the liquid level). A sample of the effluent was taken by inserting a sampling probe through the access door and placing the probe inlet in a dense portion of the mist 5 feet above the oil level.

Two of the five units were sampled. The emission rates reported were determined by expanding the results of the two tests to include all five units.

Unit F

Diesel oil is brightened continuously in a tank 30 ft. in diameter by 13 ft. high. A flat roof is placed over the tank and supported approximately 2 ft. above its shell. This leaves a 2-ft.-high space around the circumference of the tank open to the atmosphere.

Approximately 6000 barrels per day of product are processed. Air enters the tank at its base through a "spider". The air passes through approximately a 5-ft. layer of diesel oil and is discharged to the atmosphere through the circumferential space.

The sampling probe was placed in the space above the oil layer in a dense portion of the visible mist.

Unit A

Kerosine is brightened in three tanks (5-1/2 ft. in diameter by 23-1/2 ft. high, 5-1/2 ft. in diameter by 26 ft. high, and 6-1/2 ft. in diameter by 26 ft. high) packed with Raschig rings and rock. Approximately 12,000 barrels per day of kerosine are processed. The effluent air from these tanks passes overhead into a common line entering the base of a knock-out drum. The air passes upward through the knock-out drum, past a series of wooden baffles, a salt water spray and a layer of mesh packing. The vented air from the knock-out drum passes through a 12-inch diameter by 30-foot high stack to the atmosphere.

The sampling probe was placed inside the stack about 15 feet above the knock-out drum.

Sampling Procedures

The sampling train is assembled as shown in Figure 1-2. The probe 1 is placed at a point of uniform flow in the stack (if the effluent is passed through a stack to the atmosphere) or in a dense portion of the mist formed above the liquid (if the oil is processed in an open tank). The air driven vacuum pump 9 draws a portion of the atmospheric effluent through the probe into three Shepherd freeze-out traps 2 placed in series. The traps are placed in Dewar flasks which contain a slurry composed of dry ice and methyl cellosolve. The temperature within the freeze-out trap is approximately -70°C. The sample is drawn through the center portion of the trap (see Figure 1-3) to its bottom and then passes upward through the outside annular space which contains a glass wool plug. The sample (minus the material condensed out in the traps) passes through a 300-ml. mine sampling tube 3, which is kept in the line throughout the sampling period.

The sampling rate is maintained constant at some value between 1 and 1 1/2 liters per minute as measured by the rotameter 4. The period of sampling is 1 hour. As condensate (a good portion of which is water) is formed in the freeze-out trap, the pressure in the system varies. The sample rate control valve 8 must be adjusted so that the desired sampling rate is maintained.

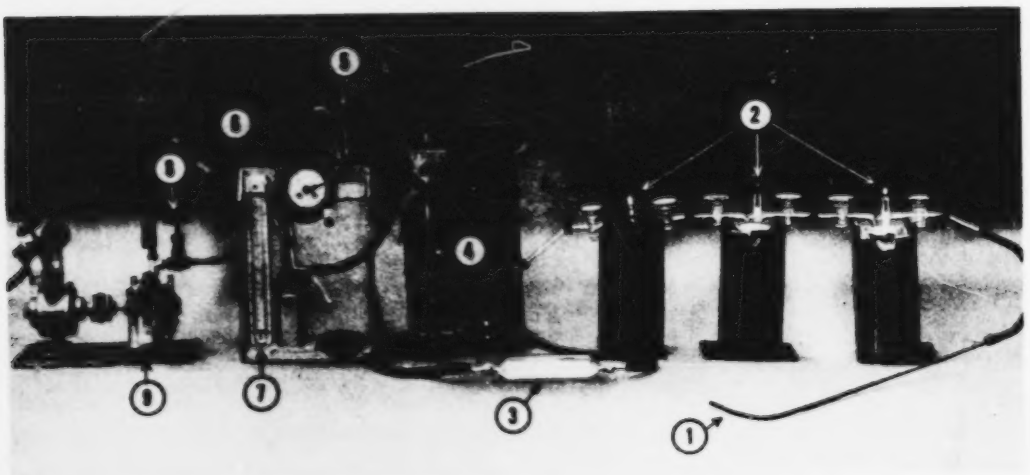

Figure 1-2. Equipment setup for sampling emissions from air blowing operations. operations.

The total volume of the sample taken is recorded on the dry gas meter 6. The temperature 5 and the pressure 7 at the meter are determined so that the recorded sample volume may be reduced to standard conditions.

Analytical Method

The Shepherd traps are evacuated to a pressure of 75 mm. Hg. abs. before removal from the dry ice slurry. This is done to prevent excessive pressure from building up within the trap as it warms to ambient temperature. The condensate is removed from the Shepherd trap by mixed phase distillation as shown in Figure 1-4.

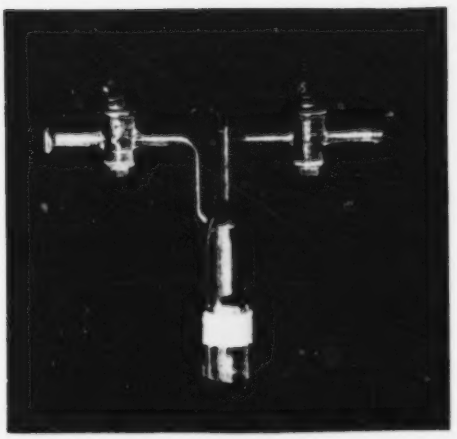

Figure I-3. Shepherd freeze-out trap.

Water is added to the condensate in the Shepherd trap and the trap is placed over an open electric coil heater 2. The stopcock at one end of the trap 3 is opened and this end is connected to a water-cooled condenser 4 leading to a centrifuge tube 5. The material captured in the trap is driven over to the centrifuge tube. After centrifuging to obtain two distinct layers, the oil layer is drawn into a micro-pipette and measured.

The contents of the traps not containing condensate are analyzed by an infrared spectrophotometer. The absorption is measured at 3.45 microns. Absorption at this wave length is attributed to the carbon-hydrogen stretching bond and the infrared instrument used is calibrated against n-hexane. The contents of the mine sampling tube placed in the line are also analyzed by the infrared spectrophotometer.

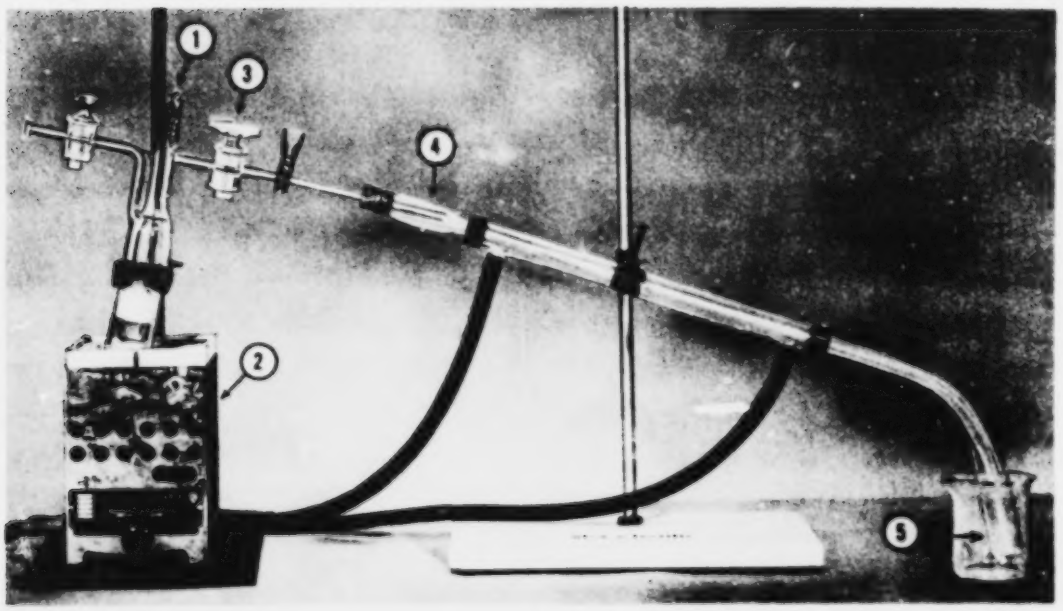

Figure I-4. Laboratory setup for mixed phase distillation.

Calculations

The volume of the oil portion of the condensate is determined as described in the previous section.

The specific gravity of the condensate is assumed to be the same as that of the material being processed.

The atmospheric emission of hydrocarbons is given by the following equation:

$$W = \frac{QDV_o}{3785V_g}$$

where

W = emission of hydrocarbons, pounds per day

Q = air rate into the unit standard cubic feet per day

D = density of the petroleum fraction being processed, pounds per gallon

V_o = volume of oily portion of the condensate, milliliters

V_g = volume of gas sample taken, as measured by the dry gas meter, standard cubic feet

Discussion and Results

Condensate was found only in the first trap in all the tests. The vapor contents of the second and third traps were measured by an infrared spectrophotometer. The hydrocarbon contents of these traps had a negligible effect upon the final emission rate. Therefore, only the condensate in the first trap was used in calculating the emission rate.

The concentration of hydrocarbons in the mine sampling tube as determined by an infrared spectrophotometer was found to be between 10 and 30 ppm. (as hexane) for all units tested. The amount of hydrocarbons emitted, as calculated using this concentration, has a negligible effect upon the emission rate calculated using the amount of oily condensate captured in the first trap.

The emission of hydrocarbons to the atmosphere from the units in operation at the time of the writing of this report was found to be as follows:

Unit	Total Emission Rate Pounds per Day
C-1, C-2, C-3, C-4, and C-5	35
Unit F	2
Unit A	905*

* Operation of Unit A is scheduled to be discontinued in the future.

SECTION 2

BLIND CHANGING

Introduction

In ordinary refinery operations a single pipe, connected through a manifold to several feeder lines, may be used to carry several different products. To avoid the possibility of contaminating one product with another, it is customary to "blind off" the unused feeder lines. This is accomplished by loosening a flanged pipe connection, inserting a flat plate between the flanges, and retightening the connection. This operation results in the spillage of some of the product in the pipe, although several devices have been developed which help to perform the operation quickly and thus reduce the spillage to a minimum. In some cases, spillage of hydrocarbons when changing blinds is obviated by pumping out the lines, replacing the product with water, or in the case of highly volatile hydrocarbons, maintaining a vacuum in the line.

Survey

As a preliminary step in the development of a plan for evaluating the hydrocarbon emissions due to blind changing, visits were made to the six major refineries in Los Angeles County. Conferences were held with their supervisory and operational personnel, and inspections were made of their operations. Thirteen other refineries were contacted and it was learned that six of them do not change blinds in the course of their operations. A questionnaire was prepared and sent to the 13 refineries that change blinds requesting that they keep an accurate two-month record of all operational blind changes on lines carrying products with volatilities as high or higher than kerosine, along with sufficient data to permit a reasonably accurate evaluation of hydrocarbon emissions to the atmosphere. Figure 2-1 shows the type of data sheet used by the petroleum companies and some typical entries.

DATA ON OPERATIONAL BLIND CHANGES

Company_____

Date	Time of Day	Type of Blind	Product Category			Reid Vapor Pressure			Where Product Spilled*	Flushed with water			Distance To Nearest Drain, ft.	Estimated Amount of Spill, gal. **
										Yes		No		
			LPG	Gaso.	Kero.	>15	15-0.5	<0.5		During Change	After Change			
4/20	3:30A	slip		X			X		concrete			X	5	5
"	3:40A	"		X			X		ground			X	no drain	1
"	8:00A	"		X			X		concrete	X	X		50	20
"	2:15P	Hamer		X			X		concrete		X		20	5
"	8:30P	slip			X			X	steel plate		X		3	10
4/21	8:15A	"	X			X			--------			X	no drain	2
"	9:00A	Hamer		X			X		concrete			X	30	0

* Specify concrete slab, ground, or other
** Equivalent volume in gallons, if a gas.

Figure 2-1. Data sheet for tabulating losses from blind changing operations with some typical entries.

Evaluation of Data

For each blind change reported, an estimate was made to the nearest quarter gallon of the amount of hydrocarbons escaping to the atmosphere. It is obvious that the various factors listed on the data sheet affect the amount evaporated, but the estimate of the actual quantity was a matter of personal judgement. Although this method of estimating the emissions is subject to considerable error, it is believed that the magnitude of the emissions is not high enough to justify a more refined treatment. The refinery operators' estimates of the amount of product spilled for each blind change might also be of doubtful accuracy, but errors here would not represent corresponding errors in the final result. In most cases the entire pad surface between the blind and the nearest drain is wetted, and it is this wetted area, rather than the amount of hydrocarbon spilled, that has the most effect on the amount of hydrocarbons evaporated.

Figure 2-2. Main oil transfer area showing manifolds enclosed with hinged blinds in the foreground.

Results and Discussion

The date of each change was requested in order to determine if any particular day of the week predominated in emissions. The total emissions were slightly higher on Friday, but not enough to be significant.

Table 2-1 lists the blind changes and emissions by company for the two-month period. Examination of this table shows the wide variation in the number of blinds changed and in the controls which reduce emissions to the atmosphere from one company to another.

Table 2-1

BLIND CHANGES AND HYDROCARBON EMISSIONS BY COMPANY
TWO-MONTH PERIOD

Company	Crude Throughput, bbls./day	No. of Changes	No. with No Emissions	Gallons Spilled	Gallons Emitted to Atmosphere
A	>100,000	298	56	1,040	395
B	10 - 100,000	5	0	22	11
C	10 - 100,000	426	0	6,974	774
D	>100,000	168	11	421	189
E	>100,000	1,276	1,132	175	64
F	>100,000	371	129	2,364	343
G	10 - 100,000	18	0	341	338
J	< 10,000	8	8	16*	0
M	< 10,000	4	0	4	2
TOTALS**		2,574	1,336	11,357	2,116

* Water only; pipelines flushed out with water before blinds changed.
** Four companies reported no blinds changed during the two-month period.

It was requested that the type of blind be reported in order to determine the relative losses from different types. The total amount of product spilled was tabulated for slip and Hamer blinds in two refineries that had approximately the same number of each. The data are listed in Table 2-II.

Table 2-II

COMPARISON OF SPILLAGE WHEN CHANGING SLIP AND HAMER BLINDS

	Slip Blinds	Hamer Blinds
Number of blinds changed	196	177
Number changed with no spillage	36	4
Number changed with some spillage	160	173
Total gallons of product spilled	797	353
Gallons spilled per change--total	4.1	2.0
Gallons spilled per change--excluding those with no spillage	5.0	2.0

One refinery also reported 42 Greenwood blind changes with an average spillage of one gallon per change.

In the reports from other refineries either the loss could not be separated by type of blind or the blinds were practically all of one type, and the data were not considered to be useful for comparison purposes.

Assuming an average specific gravity of 0.75, the emission to the atmosphere of 2,000 gallons of hydrocarbons for a 61-day period indicates emissions of 200 pounds per day.

SECTION 3

LOADING FACILITIES

Introduction

Distribution of the various finished products of the petroleum refineries in Los Angeles County, the final step in a series of complex operations and processes, requires a network of loading racks, pipe lines, marine terminals, and intermediate bulk plants serving not only Los Angeles County, but reaching out across state and even international boundaries. Approximately 90 per cent of the total output is shipped by pipe lines to either large local bulk loading stations, which in turn load tank trucks and trailers for delivery to retail outlets or to other smaller bulk stations, or to marine terminals whence tank ships deliver products to distant points. The remainder is shipped from the refineries in some form of vessel; i.e., railroad tank cars, tank trucks and trailers, or drums.

When these vessels are filled, a volume of gas is displaced by the volume of liquid loaded. This gas volume contains hydrocarbon vapors originating from the evaporation of a small amount of product remaining from the previous filling, or generated by the vaporization of the product itself as it is loaded into the container. Unless provisions are made for the collection and disposal of these hydrocarbon vapors, they escape into the atmosphere. This study concerns the determination of the emissions from filling vessels at the refineries only, and not from loading at bulk stations or marine terminals located outside the refineries.

Survey

Questionnaires were sent to the refineries on the average daily amounts of products shipped. To facilitate the submission of the data, products were divided into four categories by Reid vapor pressure; i.e., products having a Reid vapor pressure of from 1 to 4 pounds, from 4 to 8 pounds, from 8 to 12 pounds, and above 12 pounds. Products with vapor pressures less than 1 pound, representing the heavier petroleum distillates were not included since their vapor pressures were so low as to preclude any appreciable emissions. The total daily volume of products loaded from all the refineries is shown in Table 3-1.

Table 3-I

DAILY VOLUMES OF PRODUCTS SHIPPED FROM
REFINERY LOADING FACILITIES

Reid Vapor Pressure	Typical Product	Volume Loaded barrels per day				
		Tank Truck & Trailer		Tank Car		Drum or Barrel
		With Vapor Recovery	Without Vapor Recovery	With Vapor Recovery	Without Vapor Recovery	Without Vapor Recovery
Above 12	LPG	7,100	0	1,500	0	0
8-12	Motor Gasolines	51,000	400	0	2,000	40
4-8	Aviation Gasolines	13,000	0	0	500	100
1-4	Other Distillates	3,700	6,100	0	2,900	60

The hydrocarbons vented to the atmosphere when filling a vessel originate from several sources. The vessel usually contains some product, remaining from the previous filling, which tends to evaporate into the air space over it. The amount of product that vaporizes, or the degree of saturation of the air space, is influenced by the history of the vessel between fillings.

Additional hydrocarbon vapors may be produced when the vessel is filled. For example, sometimes a railroad tank car is exposed to the direct sun for several hours before filling. Under conditions like these, liquid coming in contact with the hot walls of the vessel will vaporize rapidly and produce an extra volume of gas which is vented. Splash, or 50 per cent splash, filling adds to the vaporization by causing turbulence and by breaking up the

liquid into a spray as it strikes the bottom of the vessel or the surface of the rising liquid. Additionally, the droplets created by the splashing may be entrained in the vented gas stream and evaporate when they reach the atmosphere.

Calculations and Results

Although the hydrocarbon content of the displaced gases varies, it is assumed that the average is equivalent to saturated conditions.

In calculating the weight of hydrocarbon vapors which are vented to atmosphere, it is also assumed that 1) the volume of gases is equal to the volume of liquid loaded and 2) the hydrocarbon vapor-air mixture conforms with Dalton's Law of Partial Pressures. These simplifying assumptions are considered to reflect average conditions. The weight of hydrocarbons vented to the atmosphere may then be expressed as:

$$W = \frac{Pvw}{14.7}$$

where W = weight of hydrocarbon vapors vented, pounds.

P = partial pressure of the hydrocarbon vapors in the air-vapor mixture (usually considered to be the true vapor pressure of the liquid remaining in the vessel before filling), psia.

v = the volume of product loaded, cubic feet.

w = specific weight of the hydrocarbon vapors, pounds per cubic foot.

If V is the volume of the product loaded measured in barrels (5.6 cu.ft. per bbl.) and the hydrocarbon vapors vented are considered to occupy 6.0 cubic feet per pound, then the foregoing expression reduces to:

$$W = 0.063\ PV$$

Calculations were made using the above relationship, converting the Reid vapor pressures of the products to their true vapor pressures at a yearly average temperature of 75°F. Loading of products under vapor recovery systems was considered accomplished without any hydrocarbon emissions to the atmosphere. The results of the calculations showed a total of 1800 pounds per day of hydrocarbons being emitted, as indicated in Table 3-II.

Table 3-II

EMISSION OF HYDROCARBONS TO THE ATMOSPHERE FROM REFINERY LOADING FACILITIES

Product	Reid Vapor Pressure	Hydrocarbon Emissions pounds per day
Motor Gasolines	8-12	900
Aviation Gasolines	4-8	100
Other Distillates	1-4	800
Total		1800

Discussion and Conclusions

Vapor recovery systems on loading facilities are in widespread use in the petroleum refineries of Los Angeles County (2). As shown in Table 3-I, all of the liquified petroleum gas is loaded under vapor recovery. Except for a small amount (5 per cent), loaded mostly into railroad tank cars, all the motor and aviation gasolines are loaded into tank trucks and trailers under vapor recovery. Figure 3-1 shows a typical refinery truck loading facility with a vapor collection system. Of the other petroleum distillates having a Reid vapor pressure of from one to four pounds, about 30 per cent are loaded under vapor recovery.

As shown in Table 3-II the total emissions of hydrocarbons to the atmosphere from loading facilities in Los Angeles County petroleum refineries amount to 1800 pounds per day. The contribution of the vapor systems toward reducing the emissions of hydrocarbons may be determined by calculating the emissions if vapor recovery systems were not in use, excepting the loading of LPG which is done under pressure of from 50 to 200 psig, with vapor return lines used to preclude any venting of the container to the atmosphere. Calculations show that 24, 500 pounds of hydrocarbons per

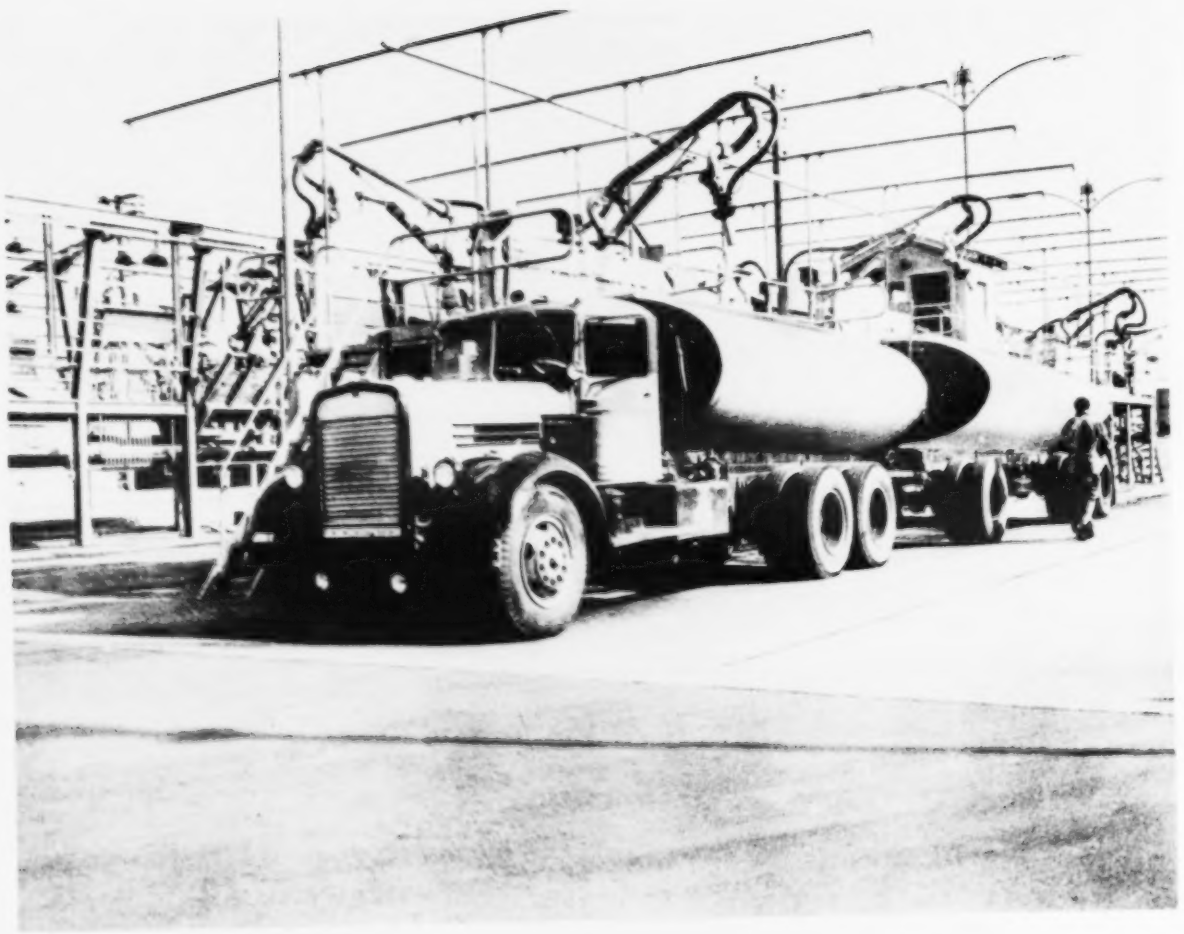

Figure 3-1. An open, overhead controlled, gasoline truck loading rack showing vapor closures and vapor return lines on pneumatically operated loading arms.

day would be emitted to the atmosphere were vapor controls not used. The reduction, therefore, amounts to 22,700 pounds per day.

SECTION 4

TURNAROUNDS, EQUIPMENT MAINTENANCE, AND BLOWDOWN SYSTEMS

Introduction

One of the essential operations of any refinery, and a source of emissions to the atmosphere, is the periodic maintenance and repair of equipment. This includes the shutting down and starting up of refining units, usually called a "turnaround," and the repair, inspection, and maintenance of storage tanks. A "blowdown" is the emptying and purging of an operating unit, often performed by letting the pressure in the unit blow the contents to a receiving vessel. To minimize the escape of hydrocarbons, a rather elaborate blowdown system is often maintained as an integral part of the unit.

No detailed description of a typical shutdown can be given. Each refinery has its own methods and procedures, and even different units in the same refinery may vary considerably in the methods of shutting down. However, a general description of shutdowns with some of the major points of difference among different companies is possible.

Most refinery units, when in operation, contain hot hydrocarbon vapors and liquids. To shut down, the fires are cut and the feed stock is circulated while the unit cools. To prevent solidification of the stock as it cools, gas oil may be introduced into the unit. The liquid is pumped out to a storage tank, leaving hydrocarbon vapors in the system. The unit is then purged with steam, nitrogen, or water, with the exhaust gases going to the fuel gas system, a vapor recovery system, a flare, or in some cases, to the atmosphere.

Usually these two operations--the "circulating down" and purging of the gases--are carried out simultaneously, so that by the time the unit is cold it is essentially free of liquid and vapor and is ready to be opened to the atmosphere. Since there are usually traces, and sometimes substantial amounts of hydrocarbon vapors in the vessels, they are thoroughly purged with air before any personnel are permitted to enter them for inspection or maintenance. Thus, it can be seen that varying amounts of hydrocarbons, from virtually none to several thousand pounds, may be emitted to the atmosphere when a unit is shut down, depending on the shutdown procedure.

Field Survey

Initially, visits were made to several refineries and conferences were held with their supervisory personnel in an attempt to devise a workable plan for the study. It was obviously impracticable to attempt any direct measurements of emissions during shutdowns, but it was believed that a questionnaire could be developed which would yield sufficient data to make a reasonably accurate estimate of the hydrocarbon emissions. Dates of scheduled turnarounds were obtained from the eight largest refineries in the County, and visits were made to observe the shutdown procedures.

Information was obtained during the inspection visits that permit some generalizations to be made. First, most scheduled shutdowns occur on weekends so that the maintenance crews can start as soon as they arrive on Monday mornings. Second, it is evident that the emissions are not continuous but occur at high emission rates for short periods of time. Thus, it would seem more realistic to express the emissions in terms of the time of their occurrence rather than as an average emission per day.

By taking into account the method of shutting down, it should be possible to make a reasonable estimate of the concentration of vapor in any given process vessel at the time it is opened to the atmosphere. The amount of hydrocarbon emissions could then be calculated if the volume of the vessel were known.

Refinery Poll

Simultaneously with the field surveys, work was started on a questionnaire to be sent to the refineries, requesting information on their turnarounds and storage tank maintenance. It was desired to frame a questionnaire in which the expenditure of time necessary to find and compile the information would be justified by its value. In a series of conferences with members of the Western Oil and Gas Association and refinery personnel, a questionnaire was drafted and sent to the eight largest refineries in the County.

The questionnaire stated, in part:

> "For process units we would like the following information from September 1, 1956, to September 1, 1957:
>
> 1. Date of shutdown.
> 2. Type of shutdown (normal or emergency).
> 3. Name of unit.
> 4. Size of unit as represented by feed input, barrels per day.

"Since tank cleaning and maintenance frequently result in the release of an entire tankful of gas or vapor to the atmosphere, and may constitute a significant source of emissions, we should have more complete data than that required for process units. For storage tank cleaning and maintenance, we would like the following information for tanks containing crude oil and products lighter than kerosine, from September 1, 1956, to September 1, 1957:

1. Date.
2. Tank identification and type.
3. Product in tank and approximate Reid vapor pressure.
4. Volume of tank. In floating roof tanks, vapor space with tank empty and roof down.
5. Method of purging or flushing, if any, and disposition of purged product.
6. Pressure in tanks after final venting to recovery or disposal system. Applies only to pressure storage tanks."

Losses from Process Unit Shutdowns

In an attempt to correlate the volume of equipment and the feed rate, the total volume of all process equipment was obtained for five refinery units. Piping was not included. The results are tabulated in Table 4-I.

Table 4-I

RATIOS OF VESSEL VOLUMES TO FEED RATES FOR A NUMBER OF MAJOR PROCESS UNITS

Unit	Feed Rate, bbl./day	Volume, cu. ft.	Volume/Feed Rate, cu. ft./bbl./day
Vacuum distillation	53,500	39,000	0.7
Thermal cracking	24,000	34,640	1.4
Thermal fractionation	3,550	10,610	3.0
Visbreaking	10,000	12,650	1.3
Catalytic cracking (2 units)	26,950	78,900	2.9
Totals	118,000	175,800	1.5

The units listed do not represent extremes as to size or age, and thus are believed to be representative of averages in the County. It is probable that the ratio of volume to feed rate for very new or very old units would vary more than those listed above, but the ratio of 1.5 cubic feet per barrel per day is probably a reasonably good average for all the refineries.

Using the turnaround data submitted by the refineries, the product of the feed rate and the number of times the unit was shut down was obtained for each unit in each refinery. These values were then summed for each refinery. Not included were units for which the data submitted by the industry on the method of shutting down indicated that the losses were negligible. Table 4-II shows the results of this compilation.

Table 4-II

CAPACITIES OF UNITS INVOLVED IN REPORTED SHUTDOWNS

Company	Number of Shutdowns (total)	Number of Shutdowns (with emissions)*	Feed Rates times Number of Shutdowns with Emissions, bbls./day
A	72	4	80,000
B	49	22	251,900
C	55	54	499,300
D	60	59	850,300
E	35	0	-
F	47	29	370,000
G	12	0	-
H	52	45	155,500
Total	382	213	2,207,000

* Shutdowns for which information submitted by the refineries did not indicate that emissions were negligible.

In order to make an estimate of the magnitude of emissions due to turnarounds, the additional assumption was made for the purpose of calculation that the emission was equivalent to the total volume of the unit filled with

butane at one atmosphere pressure and 60°F. Using these assumptions, it can be seen that for any turnaround:

$$W = \frac{Q\ (1.5)\ (58)}{(379)\ (2000)}$$

where W = emission to atmosphere, tons per day

Q = feed rate, barrels per day

1.5 = ratio from Table 4-I, cubic feet per barrel per day

58 = molecular weight of butane

379 = pound-molecular volume at 60°F.

Using this formula, the maximum emissions to the atmosphere from turnarounds are calculated to be 254 tons per year. This amounts to an average of 0.7 ton per day; however, since 60 per cent of all shutdowns occur on Sunday and Monday, the weekend (Sunday and Monday) emissions are 152 tons per year, or an average of 3 tons per weekend.

Cleaning and Maintenance of Petroleum Storage Tanks

The information obtained from the survey of tank cleaning and maintenance operations was used to estimate the quantity of hydrocarbon emissions to the atmosphere as follows:

1. When the reported procedure indicated that the vapor content of the tank was released to a controlled recovery or disposal system, prior to opening for maintenance, the emissions were considered negligible.

2. In other instances where the stored liquid was transferred to another tank and then the emptied vessel was opened for maintenance, the emission to the atmosphere was considered to be equal to the weight of hydrocarbon vapor occupying the total volume of the tank at the reported pressure. (For floating roof tanks, the minimum volume was used).

3. For vapor storage, where tanks were not purged to a controlled recovery or disposal system, estimates were made as described in 2. above.

In the case of hydrocarbon mixtures the average molecular weight of the vapor in equilibrium with the liquid is lower than that of the liquid because of the greater volatility of the lower molecular weight compounds. Knowing the Reid Vapor Pressure and the A.S.T.M. 10 per cent Point Slope of the stock, the molecular weight of the hydrocarbon vapor can be determined (3). Some of these values were calculated, and the molecular weights varied from 64 to 69.

Tests have shown that the average molecular weight of the vapor above gasoline is about 60, and this value was used in the calculations for all liquid hydrocarbons. For LPG a molecular weight of 50 was used. For pure compounds the actual molecular weights were used.

The vapor pressure at 65°F. was estimated from the Reid Vapor Pressure, and it was assumed for the purpose of calculation that the air above the liquid was saturated with hydrocarbon vapor. The weight of hydrocarbons contained in the tank and therefore emitted to the atmosphere was calculated by using the following equation:

$$W = \frac{V\ M\ P}{(383)\ (2000)\ (14.7)}$$

where W = emissions of hydrocarbons, tons

V = volume of tank vapor space, cubic feet

P = 1) vapor pressure of liquid at 65°F., psia, when the vapor pressure is less than 14.7 psia, or

2) pressure in tank after final venting to recovery or disposal system, psia, when the vapor pressure is greater than 14.7 psia.

The calculated emissions are listed in Table 4-III. These figures represent maximum emissions since the air above the liquid in most tanks is not saturated with vapor.

Table 4-III

HYDROCARBON LOSSES FROM CLEANING
AND MAINTENANCE OF STORAGE TANKS

Company	Emissions, tons 9/1/56 to 9/1/57
A	15.6
B	89.7
C	46.7
D	90.8
E	14.1
F	28.5
G	199.0
H	0.0
Total	484.4
Per Day	1.3

From Table 4-III it is seen that maximum emissions to the atmosphere from tank cleaning average 1.3 tons per day of hydrocarbon vapors, with tank cleaning operations spread more or less uniformly throughout the week.

SECTION 5

WASTE WATER SEPARATORS AND PROCESS DRAINS

Introduction

Some equipment and a number of operations in oil refineries may allow hydrocarbons to reach the drains and eventually the waste water separators. These include blind changing, sampling, turnarounds, leaks in process equipment, and spills. In addition, much of the water reaching the drains has been used for processing, cooling of pump seals, or flushing and may be already contaminated with hydrocarbons. As the hydrocarbon-water mixture flows through the system, hydrocarbons are evaporated from the surface and may escape to the atmosphere through vents.

As a prelude to a possible complete study, field inspections were made of waste water separators and process drains in all the major refineries in the County. Data obtained during these inspections indicated that the magnitude of emissions from this equipment was not sufficient to justify a complete field testing program. An estimate of hydrocarbon emissions from process drains and waste water separators is possible as a result of these initial field inspections and by the use of additional data available from the Los Angeles County Air Pollution Control District. The following report discusses this estimate and its origins.

Results of Field Inspection Trips

Field trips were made to the six major refineries in Los Angeles County to inspect the process drains and waste water treatment systems. During these visits a combustible gas indicator was used to determine the hydrocarbon vapor concentration in a number of typical locations. A titanium tetrachloride smoke tube was used to indicate the direction and approximate magnitude of the airflow around the drain and separator openings.

While details of the systems inspected varied, nearly all of them followed the pattern described below and can be conveniently divided into three main segments--collection systems, interceptor systems and oil-water separation systems.

Collection Systems

Each major unit in the refineries is generally drained by a network of small lines serving minor installations such as pumps and concrete pads in and around the unit. These drains are generally trapped at their inlets and flow into junction or collection boxes, some of which are open to the atmosphere, located near the main trunk lines (Figures 5-1 and 5-2). Tests for hydrocarbons were nearly always positive in these collection boxes with average concentrations of about the lower explosive limit* near the surface of the water. Tests with the smoke tube indicated that movement of gases out of some of these junction boxes did occur, the rate depending on the wind velocity, and the position and type of box.

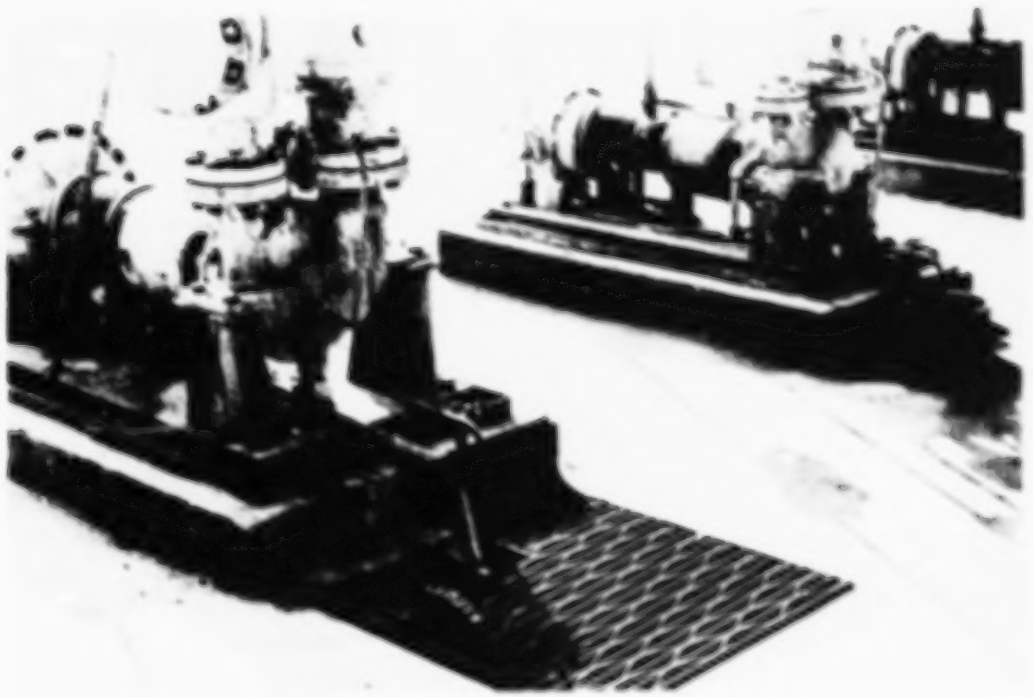

Figure 5-1. Junction box for collection system draining cooling water from a bank of centrifugal pumps.

* Lower explosive limits, listed in Special Interest Bulletin No. 161 of the National Board of Fire Underwriters and expressed as per cent by volume in air are as follows: propane, 2.2; butane, 1.8; pentane, 1.5; hexane, 1.2.

Figure 5-2. Close-up of a junction box in a typical collection system. The box, normally covered by a grate, has submerged inlets and outlets and accepts surface drainage. This junction box drains cooling water from three centrifugal pumps.

Interceptor Systems

The waste flow generally proceeds from the collection boxes through trapped outlets into a network of large trunk drains. These connect with interceptor lines which carry the process water to the separators and water treatment plant. For safety reasons, traps are usually provided at the entrance of these main lines into the separator tanks. Additional traps are often provided at each manhole along the main drain lines to impede the propagation of explosions through the systems. These manholes are usually vented through covers or elevated standpipes. A large number of tests for hydrocarbons were made in the manholes along these main drain lines near the vent or cover openings. These seldom indicated a hydrocarbon concentration greater than the lower explosive limit. Higher concentrations were noted deep in the manholes. Air movement through the cover openings and vents was usually in and out in a regular oscillatory motion. Occasionally, where steep slopes and fast liquid flow were encountered, the air motion was predominantly into the opening.

Oil-Water Separators

Waste water separators are vessels which provide a period of near quiescence of sufficient time to allow most of the hydrocarbons to rise to the surface of the water. The floating oil is skimmed off and reprocessed in the refinery. Since July 1956, all major oil-water separator boxes in oil refineries in Los Angeles County have been covered. A typical oil removal system includes a large covered compartmentalized vessel followed by an open tank or pond and a straw mat for filtration and final clarification.

Los Angeles refineries have a total of 28 separators covered or under vapor recovery. These installations process about 760,000 barrels of water daily and recover 140,000 gallons of slop oil per day. In addition to these main separators, final oil removal is accomplished through 68 uncovered ponds and secondary separators.

Except for those equipped with floating roofs, most separators have vapor spaces between the liquid level and the cover. Hydrocarbons were found in this vapor space in nearly all separators tested, with concentrations greater than the lower explosive limit common near the surface of the liquid. On a few occasions the hydrocarbon concentration deep in the separator box

was greater than the upper explosive limit (7.8 per cent by volume for pentane). Using the combustible gas indicator, no vapors were found above the occasional scum present on the open secondary flotation tanks or ponds.

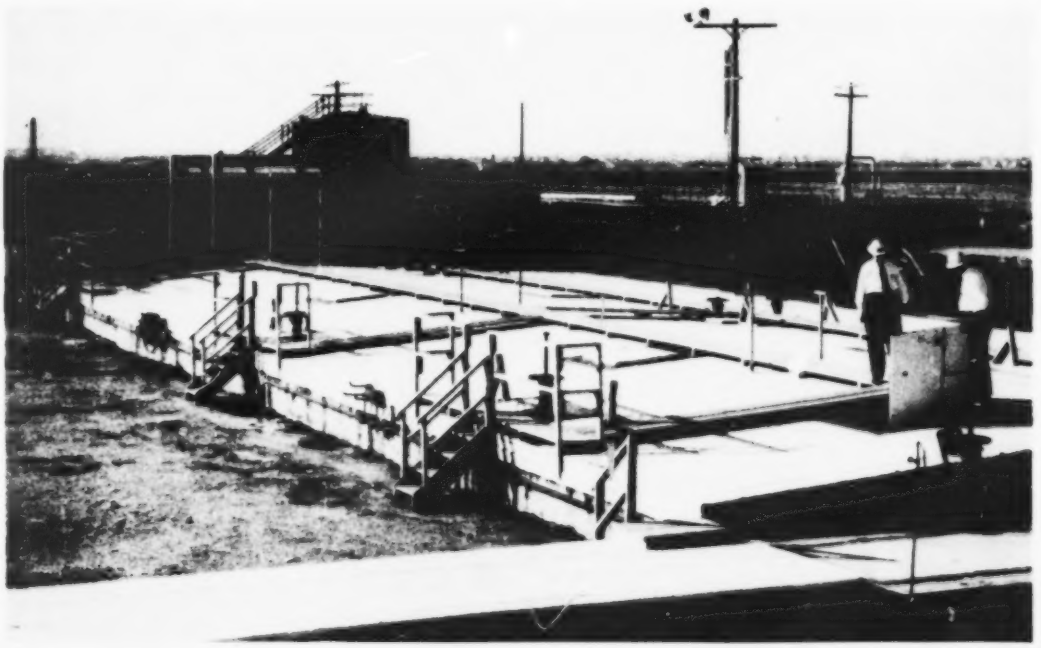

Figure 5-3. A large covered separator box.

Estimate of Atmospheric Emissions

Since only general information concerning hydrocarbon concentration and air motions were obtained on the field inspection trips no precise evaluation of atmospheric emissions is possible using these data. However, an estimate of emissions from refinery process drainage systems was available based on figures supplied for an annual Air Pollution Control District total pollution survey (4). These data show a total of 3 tons per day of hydrocarbons emitted from process drains and waste water separators. This estimate is in accord with information gained during the field inspections. Although the data obtained during this study were not sufficiently detailed to allow alteration or refinement of this existing total emission figure, they do allow some elaboration on the relative contribution of the various parts of the system to the total emissions.

Collection Systems

The collection system often makes a significant contribution to the total emissions. The junction boxes are often uncovered, the small drain inlets are not always trapped, and cleaning and cooling water is frequently conducted to the drains in open channels or ditches. When any of these conditions occur, some of the more volatile hydrocarbons escape to the atmosphere before reaching the trunk or interceptor lines.

Interceptor Systems

One refinery which has its trunk and interceptor system under vapor recovery, draws a total of 36 CFM of air in at all vent and manhole openings. Smoke tube tests showed a substantial inward flow of air even at manhole openings farthest from the separator. This information, coupled with a knowledge of the hydrocarbon concentration of the gases near the vents and openings, allowed the total emission from large drains to be approximated.

Calculations, assuming 12 CFM as the rate gas escapes from a drainage system with natural draft (this is one-third the ventilation under forced draft conditions) and the lower explosive limit as the hydrocarbon concentration of the escaping gas, gave a total emission rate of 300 pounds per day from this source in all refineries.

Waste Water Separators

Much of the emissions from waste water separators can be traced to a few poorly covered tanks. Additional leakage occurs around sampling and maintenance hatches, slop-oil collection systems and other appurtenances of almost all separator boxes.

Conclusions

The total emissions of hydrocarbons from waste water separators and process drains are about 3 tons per day. This estimate is a compilation of figures contained in the Air Pollution Control District total pollution survey and is in agreement with information gained during inspection trips made of the systems by Joint Project personnel.

The collection systems frequently appear to afford a greater opportunity for the escape of hydrocarbons than either the interceptor systems or the oil-water separators. In other areas, where oil-water separators are not covered, the greatest hydrocarbon emissions might occur from the separators.

SECTION 6

EXHAUSTS OF GAS COMPRESSOR INTERNAL COMBUSTION ENGINES

Introduction

In certain phases of petroleum refining the product involved is in the gaseous state. Vacuum distillation, thermal and catalytic cracking, polymerization, alkylation, and reforming all consume or produce large volumes of gaseous hydrocarbons. The handling and storage of these products and the gases of vapor recovery systems require many compressors. The reciprocating compressor driven by an internal combustion engine is one of several types of compressors serving these processes.

The internal combustion engine generally employed in the petroleum refineries of Los Angeles County to drive a gas compressor is a four-cycle gas engine (some two-cycle engines are also used), operating on natural gas. The power cylinders are combined with horizontal, crosshead-type, double-acting compressor cylinders in a single frame. The connecting rods of each pair of power cylinders are articulated to a main connecting rod which drives the compressor piston. A typical design has an 8-1/4-inch bore and 9-inch stroke, and is rated at 27.5 horsepower per cylinder at 550 rpm. Frequently, depending on the number of cylinders, several hundred horsepower may be developed in each engine.

The fuel burned, natural gas, has the following composition:

Component	Volume per cent
Methane	82.0
Ethane	9.1
Propane	3.4
N-butane	0.2
Iso-butane	0.2
Pentanes	0.1
Nitrogen	5.0

Heating value: 1085 Btu. per cubic foot
Specific gravity: 0.668 (air = 1.0)

Although these engines are operated at steady load conditions which promote good efficiency, some of the fuel passes through the engine and out the exhaust unburned. In addition, as a result of nitrogen fixation in the combustion cylinder, oxides of nitrogen are found in the exhaust gases. Other air contaminants, such as ammonia and aldehydes, may also be present.

Operating Data

The six major companies operating 95 per cent of the gas compressor engines in Los Angeles County petroleum refineries were requested to submit operating data on their engines and results of any tests made on the exhaust gases. The information obtained is summarized below:

Number of compressor engines	130
Fuel gas burned, MCFD	10,500
Exhaust gas, SCFM	165,000
Hydrocarbons in exhaust, ppm.	1,240
Oxides of Nitrogen as NO_2 in exhaust, ppm.	315

The composition of the exhaust hydrocarbons was generally over 90 per cent methane, and over 95 per cent methane and ethane.

A few tests conducted by one refinery previous to this study showed concentrations in the exhaust gases of ammonia (200 ppm.) and aldehydes (60 ppm.), but additional confirming data for these contaminants were unobtainable.

Calculations

The emission of contaminants was calculated from the foregoing data using the following expression:

$$W_c = \frac{1440\, C_c\, M_c\, Q}{(2000)(379)(10^6)}$$

where W_c = the emission of a particular contaminant, c, tons per day

C_c = concentration of contaminant c in exhaust gases, parts per million by volume

M_c = molecular weight of contaminant c

Q = exhaust gas rate, standard cubic feet per minute

The results of the calculation are shown in Table 6-I.

Table 6-I

EMISSIONS OF AIR CONTAMINANTS FROM EXHAUSTS OF GAS COMPRESSOR INTERNAL COMBUSTION ENGINES

Contaminant	Emissions, tons per day
Hydrocarbons (90% methane)	6.5
Oxides of nitrogen, as NO_2	4.5

Discussion

In calculating the emissions of hydrocarbons, an average molecular weight of 17 was used since the hydrocarbons in the exhaust were generally over 90 per cent methane, and over 95 per cent methane and ethane.

The amount of fuel gas consumed was determined either by direct metering or indirectly from the design fuel gas requirement in Btu. per horsepower, the average Btu. content of the fuel gas, and the average horsepower requirements. Exhaust gas volume was calculated stoichiometrically from the fuel gas volume and composition, and Orsat analysis of the exhaust gases.

Concentration of the hydrocarbons was determined by analysis of the exhaust gases by mass spectrometer, infrared spectrophotometer, or gas chromatograph. Oxides of nitrogen were determined by the phenoldisulfonic acid method (5). The Kjeldahl method was used to determine ammonia (6), and a modified sodium bisulfite method for determining aldehydes (7).

Conclusions

Air contaminants emitted into the atmosphere from exhausts of gas compressor internal combustion engines include hydrocarbons, oxides of nitrogen, ammonia, and aldehydes. The hydrocarbons, generally over 95 per cent methane and ethane, amount to 6.5 tons per day. Total oxides of nitrogen, as NO_2, account for 4.5 tons per day. Small amounts of ammonia, and aldehydes are also emitted.

SECTION 7

WASTE GAS FLARES

Introduction

Modern refining processes produce large quantities of hydrocarbon gases. For reasons of economy any steady production of gas is sold, converted to other products, or used as a fuel within the plant. However, every refinery must be equipped to handle excess gas production which is produced intermittently and large volumes of hydrocarbon vapors produced very rapidly from process units during emergencies. A number of devices are utilized to recover these gases but facilities for the ultimate disposal of excess vapors are usually necessary. This is generally accomplished by combustion in waste gas flares although small amounts may be vented to the fireboxes of heaters or boilers.

Types of Flares

The objective of combustion in a waste gas flare is the oxidation of the hydrocarbon vapors to carbon dioxide and water without the production of smoke and objectionable odors. To obtain smokeless combustion the following conditions must be met:

1. The heating values of the waste gases must be adequate to maintain combustion.

2. An adequate air supply must be maintained.

3. Intimate mixing of fuel and air must be accomplished.

A number of combustion techniques and flare designs are in use in an attempt to maintain these factors at optimum levels within practical economic limitations. Two types of waste gas flares are used in refineries located in Los Angeles County. These are the air-inspirating venturi flare, and the steam-injected flare. Both types are known as "smokeless" flares.

The venturi-type flare (8) supplies an adequate amount of combustion air and insures proper mixing by passing the waste gases through a venturi throat near the tip of the flare. Air is inspired at the venturi throat and

mixed with the waste gases before being discharged into the combustion zone. To provide sufficient air for complete combustion at all waste gas flow rates, a series of burners of varying capacities must be provided. In Los Angeles County, venturi-type flares are used by most of the smaller independent refineries and as an auxiliary installation at one major refinery.

The steam-injected smokeless flare is used by all major refineries located in Los Angeles County. In these units steam at high pressures is injected into the waste gas stream at the flare tip. The jet action at the steam nozzle entrains air and causes sufficient turbulence for good mixing. The use of steam results in additional important benefits (9):

1. The steam reacts with the fuel, probably to form oxygenated compounds that burn readily at low temperatures. Water-gas reactions also may occur.

2. The steam reduces the partial pressure of the fuel, and the separation of the hydrocarbon molecules retards polymerization.

In nearly all installations the flare is preceded by accessories which control the steamflow and provide for the safe operation of the unit. This auxiliary equipment usually includes by-pass valves, flame arresters, water seals, and knockout drums to remove entrained liquid droplets from the waste gas stream.

Emissions from Flares

Although the burning pits or simple pipe flares once used for the combustion of waste gases appeared to be a major contributor to atmospheric pollution (Figure 7-1), the smokeless flares now in operation appear to attain highly efficient combustion of the waste gases. Actual field testing of flares by the Joint Project staff was not feasible because of safety considerations, the erratic nature of the gas flow to flares and the inaccessibility of most flare tips. However, some data from a flare test was made available to the Joint Project Committee. This test was made on a steam-injected, elevated flare operated in another county in California. These data presented below in the form of ratios of hydrocarbon and carbon monoxide to carbon dioxide in the combustion products confirm the impression

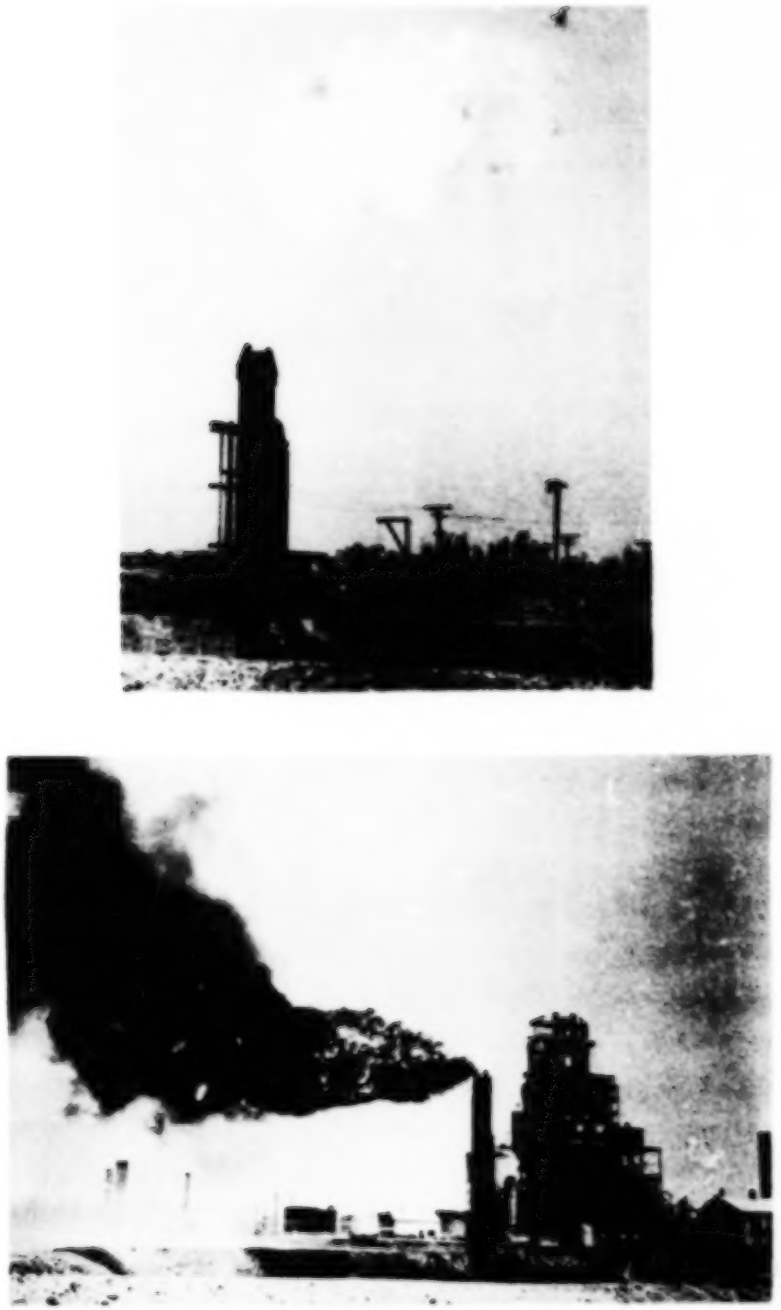

Figure 7-1. Elevated flare showing the effect of steam injection. Top, burning with steam injection. Bottom, the same installation without steam injection.

gained from field observations that essentially complete combustion is attained in flares using steam injection.

CO_2:	hydrocarbon	2100:	1
CO_2:	CO	243:	1

Conclusions

Based on the smokeless operation and the data presented above it is concluded that essentially complete combustion occurs in the flares used in local refineries, and that emissions of organic vapors and particulate matter from this source are negligible.

Depending on the composition of the waste gas and the temperatures in the combustion zone, oxides of sulfur and oxides of nitrogen may be released as a result of the operation of these flares.

SECTION 8

VACUUM JETS

Introduction

All of the major refineries and many of the independent refineries in Los Angeles County operate some of their process equipment at less than atmospheric pressure. The charge stock is usually reduced crude or residuum and the processes are known as vacuum flashing, vacuum reduction, crude vacuum distillation, or residuum stripping. This equipment is usually used to split the charge stock into a catalytic cracking feed stock and heavy residuum for asphalt or fuel oil, with some by-product gas.

The common method for producing and maintaining a vacuum in refinery process equipment is the use of a steam-driven vacuum ejector, or jet. Absolute pressures of less than 50 mm. of mercury can be attained in the equipment served by a vacuum jet system.

The high-volume vacuum jet systems often consist of several ejector stages in series with interstage condensers (Figure 8-1). The vacuum in the process equipment is produced by the flow of steam through a nozzle into a venturi-type throat connected to the vapor space of the vacuum tower through condensers and accumulators. The steam educts the vapors and gases from the equipment and thus lowers the pressure. Effluent from the first-stage ejector in a multiple-stage system is usually passed through a condenser which condenses the steam and some of the vapors. The non-condensables are educted into the second-stage ejector, in turn followed by its condenser, and so on.

Control of Emissions from Vacuum Jets

In the initial inspections of refineries by Los Angeles County Air Pollution Control District personnel in 1949 and 1950, the non-condensable gases from the last stage of the vacuum jet system were generally found to be venting to the atmosphere. The charge stock for many vacuum units is preheated in a furnace which promotes cracking and vaporization of light fractions at the reduced pressures employed. Some of these light fractions, which are often malodorous, were not condensed by the vacuum jet condensers and were thus

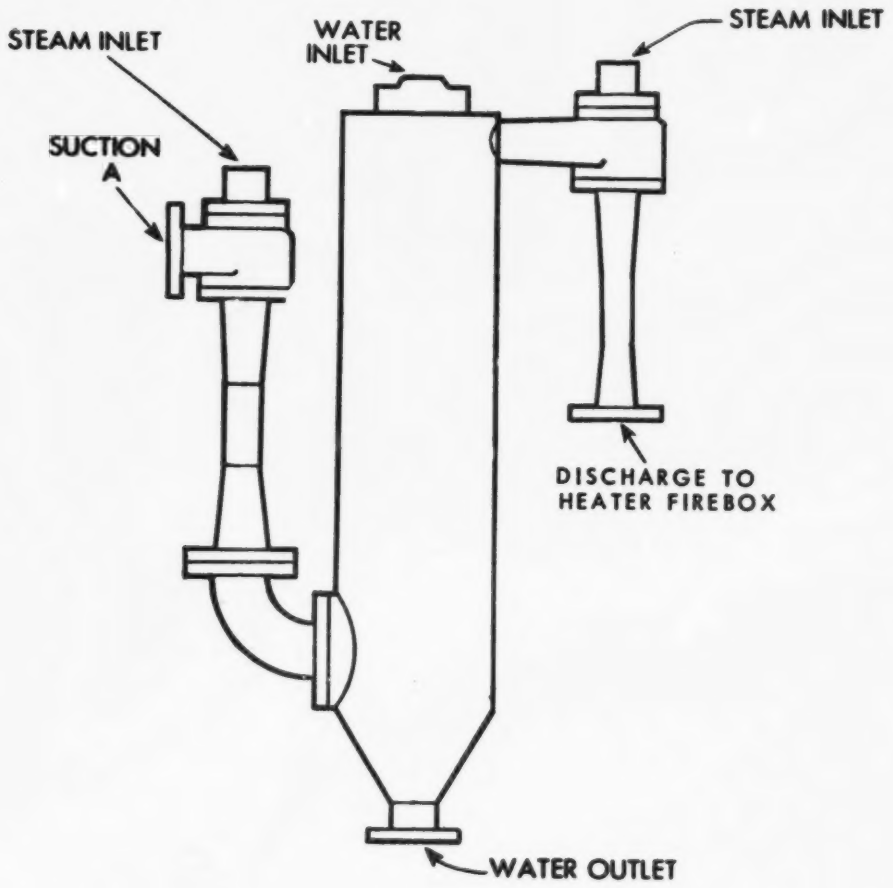

Figure 8-1. Schematic drawing of a two-stage, steam vacuum jet.

emitted to the atmosphere. Estimates of the quantity of hydrocarbons emitted from this type of source ranged from 17 tons in 1951, 7 tons in 1953, 0.2 ton in 1955, and 0 tons in 1957*

* Data from the Los Angeles County Air Pollution Control District's total air pollution statistics.

The progressive decreases in emissions from year to year correspond to control installations made. Control of emissions from vacuum jets has been extremely effective. Control is accomplished by condensing as much of the vacuum jet effluent as is practical and recovering the remaining gases and vapors and venting them to a fume incinerator or the firebox of an existing boiler or heater. The liquid condensate can be separated into water and hydrocarbon. Since all known refinery vacuum jets have been controlled by this method, it was not necessary for the Joint Project to conduct any sampling or testing program as the losses could be assessed as negligible.

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